(English Translation of JP 09-29032P)
DOCUMENT NAME SPECIFICATION

TITLE OF INVENTION

ACTIVE MATRIX LIQUID CRYSTAL DISPLAY PANEL

CLAIMS

1. An active matrix liquid crystal display panel, comprising:

a plurality of scanning lines and a plurality of signal lines disposed in an intersecting relationship with each other like gratings on one of a pair of transparent insulating substrates, a plurality of active elements individually provided in the proximity of intersecting points of said scanning lines and said signal lines, a plurality of pixel electrodes connected to said active elements, a plurality of opposing electrodes disposed corresponding to said pixel electrodes, a voltage being applied between said pixel electrodes and said opposing electrodes, a liquid crystal layer disposed between the one transparent insulating substrate and the other transparent insulating substrate, a pair of polarizing plates disposed on the outer sides of said transparent insulating substrates, and a mechanism for controlling a display with an electric field substantially parallel to said liquid crystal layer,

characterized in that an optical compensation layer having a negative refractive index anisotropy in a one axis direction, a projection of the anisotropic axis of said

optical compensation layer on a plane of one of said substrates being parallel to at least one of polarization axes of said two polarizing plates, said optical compensation layer being disposed at least between the one transparent insulating substrate and a corresponding one of said polarizing plates.

2. An active matrix liquid crystal display panel as claimed in claim 1, characterized in that , when the voltage between said pixel electrodes and said opposing electrodes is 0, angles formed by directors of liquid crystal molecules in said liquid crystal layer with respect to a plane of said liquid crystal layer are substantially uniform, and the refractive index anisotropic axis of said optical compensation layer extends substantially in parallel to said directors.

3. An active matrix liquid crystal display panel as claimed in claim 1, characterized in that a product $\Delta n_{LC} \cdot d_{LC}$ of a refractive index anisotropy Δn_{LC} and a layer thickness d_{LC} of said liquid crystal layer is substantially equal to a product $\Delta n_F \cdot d_F$ of the refractive index anisotropy Δn_F and a layer thickness d_F of said optical compensation layer.

4. An active matrix liquid crystal display panel as claimed in claim 1~3, characterized in that a refractive index n_{LO} of said liquid crystal layer for ordinary light and a refractive index n_{FO} of said optical compensation layer for ordinary light are substantially equal to each other.

5. An active matrix liquid crystal display panel as claimed in claim 1, characterized in that,

when a potential difference between said pixel electrodes and said opposing electrodes is 0, projections of directors of liquid crystal molecules in said liquid crystal layer on a plane of said liquid crystal layer are substantially parallel to each other and a projection of the refractive index anisotropic axis of said optical compensation layer on the plane of said liquid crystal layer is parallel to the projections of said directors on the plane of said liquid crystal layer, and

where an angle of the refractive index anisotropic axis of said optical compensation layer with respect to the plane of said liquid crystal layer is represented by θ_F and angles between said directors and the plane of said liquid crystal layer on interfaces between said liquid crystal layer and said insulating substrates are represented by θ_1 and θ_2, θ_1 and θ_2 being different from each other, the angle θ_F satisfies $\theta_1 < \theta_F < \theta_2$ or $\theta_2 < \theta_F < \theta_1$, and the refractive index anisotropic axis of said optical compensation layer is parallel to the director of at least one of the liquid crystal molecules in said liquid crystal layer.

6. An active matrix liquid crystal display panel as claimed in claim 1, characterized in that,

when a potential difference between said pixel electrodes and said opposing electrodes is 0, projections of directors

of liquid crystal molecules in said liquid crystal layer on a plane of said liquid crystal layer are substantially parallel to each other and a projection of the refractive index anisotropic axis of said optical compensation layer on the plane of said liquid crystal layer is parallel to the projections of said directors on the plane of said liquid crystal layer, and

where an angle of the refractive index anisotropic axis of said optical compensation layer with respect to the plane of said liquid crystal layer is represented by θ_F and angles between said directors and the plane of said liquid crystal layer on interfaces between said liquid crystal layer and said insulating substrates are represented by θ_1 and θ_2, θ_1 and θ_2 being different from each other, the angle θ_F always satisfies $\theta_1 < \theta_F < \theta_2$ or $\theta_2 < \theta_F < \theta_1$, and the angle θ_F varies in a thicknesswise direction of said optical compensation layer in a corresponding relationship to a variation of the director in the thicknesswise direction of said liquid crystal layer.

DETAILED EXPLANATION OF THE INVENTION

[Technical field to which the invention pertains]

This invention relates to an active matrix liquid crystal display panel of the structure wherein liquid crystal is held between transparent insulating substrates.

[Prior art]

In recent years, in order to achieve a higher quality of a liquid display, a displaying method called in-plane switching mode (hereinafter referred to simply as ▒IPS▒) which makes use of a transverse electric field in order to improve the visibility angle characteristic has been proposed. An example was published in "Asia Display '95 "held in October 10 to 18, 1995 and is disclosed in "Principles and Characteristics of Electro-Optical Behaviour with In-Plane Switching Mode", a Collection of Drafts for the Asia Display `95. The liquid crystal panel disclosed is constructed such that, as shown in FIG. 11, a linear pixel electrode 41 and a linear opposing electrode 42 are formed in parallel to each other on one of a pair of substrates 40 between which a liquid crystal layer is held, but no electrode is formed on the other substrate. A pair of polarizing plates 43 and 44 are formed on the outer sides of the substrates 40 and have polarization axes 45 and 46 extending perpendicularly to each other. In other words, the polarizing plates 43 and 44 have a positional relationship of a cross nicol to each other. A voltage is applied between the pixel electrode 41 and the opposing electrode 42 to produce a transverse electric field 47 parallel to the plane of the liquid crystal layer, whereupon the directions of the directors of liquid crystal molecules are varied from an initial orientation direction 48 thereby to control transmission light through the liquid crystal layer.

In the twisted nematic mode (hereinafter referred to

simply as "TN"), since liquid crystal molecules rise three-dimensionally from the plane of the liquid crystal layer, the manner in which the liquid crystal layer looks is different whether it is viewed in a direction parallel to the directors of rising liquid crystal molecules or in another direction normal to the liquid crystal layer. Further, there is a problem in that, when the liquid crystal display panel is viewed from an oblique direction, the relationship between the applied voltage and the transmission light amount is different very much. More particularly, as seen from a voltage-transmission factor characteristic illustrated as an example in FIG. 12, where a liquid crystal display panel of the TN mode is viewed from the front, the characteristic makes a monotonously decreasing curve wherein the transmission factor decreases as the applied voltage increases after it exceeds 2 V. However, where the liquid crystal display panel of the TN mode is viewed from an oblique direction, the characteristic makes such a complicated curve having extremal values that, as the applied voltage increases, the transmission factor decreases once until it comes to 0 at the voltage of 2 V, but as the voltage thereafter increases, the transmission factor increases until it decreases again after the voltage exceeds approximately 3 V. Accordingly, if the driving voltage is set based on the voltage-transmission factor characteristic when the liquid crystal display panel is viewed from the front, then when the liquid crystal display panel is viewed from an oblique direction, there is the

possibility that gradation reversal may occur such that a white displaying portion looks black or a black displaying portion becomes whitish. After all, normally the display of the liquid crystal display panel of the TN mode is visually observed correctly and can be used only within the range of the angle of visibility of 40 degrees in the leftward and rightward directions, 15 degrees in the upward direction and 5 degrees in the downward direction. Naturally, the upward, downward, leftward and rightward directions can be modified by the installation of the liquid crystal display panel.

On the other hand, the in-plane switch (IPS) system is advantageous in that, since liquid crystal molecules move only in directions substantially parallel to the plane of the liquid crystal layer (two-dimensionally), a substantially similar image can be obtained as viewed from an angle of visibility wider than that of the TN system. Particularly, the IPS system can be used within the range of an angle of visibility of 40 degrees in the upward, downward, leftward and rightward directions.

As apparatus of the IPS system, various liquid crystal display panels have been proposed which have various constructions depending upon the initial orientation condition of the liquid crystal layer and the manner of setting of polarizing plates. In the example of FIG. 11 described above, the liquid crystal layer is processed by interface orientation processing in the same direction for the two substrates and the polarization axis of one of the two

polarizing plates extends in parallel to the orientation direction. This liquid crystal display panel allows a stabilized black display since, in the initial orientation condition, the directors of liquid crystal molecules are oriented uniformly in the direction of the interface orientation processing and black is displayed when no voltage is applied, but when a voltage is applied, the directors are turned so that white is displayed.

[Problems that the invention is to solve]

As described above, with an active matrix liquid crystal display panel of the IPS system which makes use of a transverse electric field, a good display characteristic can be obtained over an angle of visibility wider than that of the conventional TN system. However, also the active matrix liquid crystal display panel of the IPS sometimes suffers from gradation reversal depending upon the angle at which the active matrix liquid crystal display panel is viewed. Where gradation reversal occurs in this manner, there is a problem that, if an image principally of a black color such as hair of a human being is displayed, then a good image cannot be obtained when it is viewed from an oblique direction to the active matrix liquid crystal display panel.

This problem is described in more detail below. First, the transmission factor where the liquid crystal layer is omitted and only two polarizing plates are disposed in a positional relationship of a cross nicol to each other. It is to be noted that, of the two polarizing plates, that one

which is disposed on the light incoming side is a polarizer, and the other one which is disposed on the light outgoing side is an analyzer.

In FIG. 13, the unit vector in the absorption axis direction of the polarizer is represented by e_1, the unit vector in the absorption axis direction of the analyzer by e_2, and the unit vector in the substrate normal direction by e_3. Those unit vectors extend perpendicularly to each other. The unit vector in the direction of a ray when it passes through the polarizer is represented by k. Where the angle between the vector k and the substrate normal line is represented by a zenithal angle α and the angle between a projection of the vector k on the plane of a substrate and the vector e_1 is represented by an azimuth ϕ, the vector k is represented as

$$k = \sin\alpha\cos\phi\cdot e_1 + \sin\alpha\cdot\sin\phi\cdot e_2 + \cos\alpha\cdot e_3 \qquad (1)$$

Light when it passes through the polarizer can be considered to be composed of a polarized light component of the (e_1 x k) direction and another polarized light component of the ((e_1 x k) x k) direction. It is to be noted that the symbol "x" between vectors represents the product of the vectors. Since the former is normal to the absorption axis e_1, theoretically it is not absorbed. On the other hand, the latter is absorbed by the polarizer. If the product of the absorption coefficient and the film thickness of the polarizer is sufficiently large, then the latter polarized light component is 0 after the light passes through the polarizer.

The refractive indices of the two polarizing plates (polarizer and analyzer) are substantially equal to each other and the directions of the ray when it passes through the analyzer is equal to k, when the ray passes through the analyzer, the light is separated into a polarized light component of the (e_2 x k) direction and another polarized light component of the ((e_2 x k) x k) direction. The latter polarized light component is absorbed substantially completely during passage through the analyzer while only the former polarized light component remains. Accordingly, if the influence of reflection at the surface of the glass and so forth is ignored, then the transmission factor T is represented as

$$T = \left\{ \frac{1}{\sqrt{2}} \cdot \frac{e_1 \times k}{|e_1 \times k|} \cdot \frac{e_2 \times k}{|e_2 \times k|} \right\}^2 \qquad (2)$$

By representing the expression (8) using α and ϕ,

$$T = \frac{1}{2} \cdot \frac{\sin^4 \alpha \cdot \sin^2 \phi \cdot \cos^2 \phi}{\sin^4 \alpha \cdot \sin^2 \phi \cdot \cos^2 \phi + \cos^2 \alpha} \qquad (3)$$

is obtained.

When light comes in from an azimuth equal to the direction of the absorption axis of one of the polarizing plates such as where the azimuth ϕ is 0 degree or 90 degrees, the transmission factor T is 0 from the expression (2). In other words, similarly to the case wherein light comes in from the front, the light does not pass due to the action of the polarizing plates which are at the positions of a cross nicol.

On the other hand, where the azimuth ϕ = 45 degrees, that is, where the azimuth ϕ defines 45 degrees with respect to each of the absorption axes of the two polarizing plates, as the zenithal angle α increases, the transmission factor increases. Where the refractive index of the polarizer is 1.5, since the refractive index of the air is approximately equal to 1, the highest value of $\sin\alpha$ is approximately 1/1.5. If this is substituted into the expression (3) to calculate it, the resulting transmission factor is approximately 7 %. Actually, however, since reflection occurs at the interface between each of the polarizing plates and the air due to the difference in refractive index between them, if a simulation is performed taking the reflection into consideration, then the relationship between the inclination angle (zenithal angle) α of the ray in the air with respect to a normal to the substrate and the transmission factor is such as indicated by a curve 1 of FIG. 14.

Next, another case is described wherein liquid crystal having a positive dielectric constant anisotropy and having a refractive index anisotropy with n_o = 1.45 and Δn = 0.067 is held between two polarizing plates such that the directors are oriented in the same direction (α = 90 degrees and ϕ = 0 degree) as that of the absorption axis of the analyzer. Light having passed through the polarizer advances, in the liquid crystal, in a direction a little different from the

direction of the light in the polarizer. As a result, the linearly polarized light polarized uniformly when it passes through the polarizer becomes elliptically polarized light after it passes through the liquid crystal. Consequently, the transmission factor is different from that where the liquid crystal is absent. The relationship between the zenithal angle α and the transmission factor when light comes in from the direction of the azimuth $\phi = 45$ degrees is indicated by a curve 2 in FIG. 14. In this instance, the transmission factor is rather higher than that (curve 1) where only the polarizing plates of a cross nicol are arranged while no liquid crystal layer is present.

On each substrate interface, the liquid crystal directors do not extend completely parallel to the plane of the substrate but normally rise by approximately 1 to 10 degrees with respect to the plane of the substrate. This angle is a pretilt angle. Usually, since, in order to orient liquid crystal with a higher degree of stability, interface orientation processing such as rubbing is performed such that the orientation directions of liquid crystal molecules may extend in parallel to each other in the proximity of each interface, the liquid crystal molecules are inclined by a fixed angle with respect to the plane of the substrate substantially in all regions. Where an orientation film for industrial use which is high in stability is employed, generally the pretilt angle is approximately 3 degrees.

The relationship between the zenithal angle α and the

transmission factor where the pretilt angle is 3 degrees and light comes in from the direction of the azimuth ϕ = 45 degrees is such as indicated by a curve 3 in FIG. 14. Further, the relationship between the zenithal angle α and the transmission factor where the pretilt angle is -3 degrees and light comes in from the direction of the azimuth ϕ = 45 degrees is such as indicated by a curve 4 in FIG. 14. It is to be noted that the pretilt angle when the liquid crystal rises in the same direction as the vector e_1 is taken as positive, and the pretilt angle when the liquid crystal rises in the opposite direction to the vector e1 is taken as negative. Particularly where the liquid crystal rises in the same direction as the vector e_1 (where the pretilt angle is positive), the transmission factor has a value approximately twice that in the case where only the polarizing plates are present (no liquid crystal is present).

Since the curves 1 to 4 of FIG. 14 exhibit comparison among black display conditions when no electric field is applied to the liquid crystal as described above, preferably the transmission factor is as low as possible. However, the curve 3 has a very high transmission factor comparing with the curves 1, 2 and 4. Therefore, the case of the curve 3, that is, the case wherein the pretilt angle is 3 degrees, is described in more detail.

While description has been given above of the case wherein no electric field is applied to the liquid crystal, if a

transverse electric field is applied to the electric field to turn the directors in the plane of the liquid crystal layer, then the transmission factor increases. According to a simulation by calculation, the transmission factor when the potential difference between a pixel electrode and a common electrode is 3 V is approximately 2.4 %, and the transmission factor when the potential difference is 3.5 V is approximately 6.3 %. FIG. 15 shows graphs obtained by plotting results of calculation of the transmission factor variation when the zenithal angle α is varied while the pretilt angle is 3 degrees and azimuth ϕ = 45 degrees. When no electric field is applied (V = 0 V), the graph is same as the curve 3 of FIG. 14 described hereinabove. When an electric field is applied, a result is obtained that, as the zenithal angle α increases, the transmission decreases, and the curve for V = 3.0 V crosses in the proximity of the zenithal angle α = 37 degrees, but the curve for V = 3.5 V crosses in the proximity of the zenithal angle α = 50 degrees, with the curve for V = 0 V when no electric field is applied (when the liquid crystal is in the initial orientation condition), and thereafter the transmission factor and the brightness are reversed. In other words, when the potential difference is 3.0 V, where the zenithal angle α is smaller than 37 degrees, the transmission factor is higher where a voltage is applied than where no voltage is applied, but where the zenithal angle α exceeds 37 degrees,

the transmission factor is lower where a voltage is applied than where no voltage is applied. Accordingly, where the zenithal angle α exceeds 37 degrees, a voltage applied portion becomes rather black while a no-voltage applied portion becomes rather white, and so-called gradation reversal wherein the black and white displays are reversed to ordinary black and white displays occurs. It is to be noted that, since the transmission factors at a voltage applied portion and a no-voltage applied portion are not much different from each other in the proximity of the zenithal angle α = 37 degrees, the contrast is small and the display image cannot be observed well. Similarly, where the potential difference is 3.5 V, gradation reversal wherein the transmission factors between a voltage applied portion and a no-voltage applied portion are reversed to each other occurs around the zenithal angle α of 50 degrees.

The phenomenon of gradation reversal described above is observed also with actual devices. Although depending upon the relationship between the pretilt angle of the liquid crystal and the directions of absorption axes of the polarizing plates, depending upon a direction in which the active matrix liquid crystal display panel is viewed, gradation reversal sometimes occurs when the display panel is viewed from an angle of 40 degrees.

In this manner, with the active matrix liquid crystal display apparatus of the IPS system which is constructed using

a transverse electric field, while a good display characteristic is obtained over a wider angle of visibility than that of the conventional TN system, there is a problem in that, depending upon a direction in which the display apparatus is viewed, gradation reversal occurs, and particularly where a display which includes much black is viewed from an oblique direction, a good image cannot be obtained.

As described above, when a substrate is viewed obliquely from a direction of, for example, 45 degrees with respect to the polarization axes of two polarizing plates which are in a positional relationship of a cross nicol, a white floating phenomenon occurs because a phenomenon that, at a portion at which no voltage is applied, transmission light from one of the polarizing plates is absorbed but not completely by the other polarizing plate occurs. Further, since liquid crystal having a refractive index anisotropy is held between the two polarizing plates, the degree of the white floating phenomenon of the liquid crystal display panel is not fixed because light (linearly polarized light) having passed through one of the polarizing plates undergoes double refraction so that it is changed into elliptically polarized light, which enters the other polarizing plate. Where the directors of the liquid crystal on the plane of the substrate are oriented such that projections thereof extend in parallel to the polarization axis of one of the polarizing plates and they define a fixed pretilt angle with respect to the plane of the substrate as

in an ordinary liquid crystal display which makes use of a transverse electric field, as seen in FIG. 14, the white floating intensity becomes very high depending upon the rising direction of the liquid crystal. if the white floating is intensified in this manner, then gradation reversal sometimes occurs at a low zenithal angle as seen in FIG. 15.

It is an object of the present invention to provide an active matrix liquid crystal display panel which suppresses rather white coloring of a black display portion without losing a good visibility angle characteristic of a transverse electric field display and has a good display characteristic free from gradation reversal over a larger visibility angle range.

[Means for solving the problems]

In order to attain the objects described above, according to another aspect of the present invention, there is provided an active matrix liquid crystal display panel, comprising a plurality of scanning lines and a plurality of signal lines disposed in an intersecting relationship with each other like gratings on one of a pair of transparent insulating substrates, a plurality of active elements individually provided in the proximity of intersecting points of the scanning lines and the signal lines, a plurality of pixel electrodes connected to the active elements, a plurality of opposing electrodes disposed corresponding to the pixel electrodes, a voltage being applied between the pixel electrodes and the opposing electrodes, a liquid crystal layer disposed between the one

transparent insulating substrate and the other transparent insulating substrate, a pair of polarizing plates disposed on the outer sides of the transparent insulating substrates, and a mechanism for controlling a display with an electric field substantially parallel to the liquid crystal layer, and an optical compensation layer having a negative refractive index anisotropy in a one axis direction, a projection of the anisotropic axis of the optical compensation layer on a plane of one of the substrates being parallel to at least one of polarization axes of the two polarizing plates, the optical compensation layer being disposed at least between the one transparent insulating substrate and a corresponding one of the polarizing plates.

Where the active matrix liquid crystal display panel is constructed such that, when the voltage between the pixel electrodes and the opposing electrodes is 0, angles formed by directors of liquid crystal molecules in the liquid crystal layer with respect to a plane of the liquid crystal layer are substantially uniform, and the refractive index anisotropic axis of the optical compensation layer extends substantially in parallel to the directors, the accuracy in compensation by the optical compensation layer is improved.

Where a product $\Delta n_{LC} \cdot d_{LC}$ of a refractive index anisotropy Δn_{LC} and a layer thickness d_{LC} of the liquid crystal layer is substantially equal to a product $\Delta n_F \cdot d_F$ of the refractive index anisotropy Δn_F and a layer thickness d_F of the optical

compensation layer, the compensation accuracy can be further improved.

Where a refractive index n_{LO} of the liquid crystal layer for ordinary light and a refractive index n_{FO} of the optical compensation layer for ordinary light are substantially equal to each other, the degree of compensation can be further improved.

Preferably, the active matrix liquid crystal display panel is constructed such that, when a potential difference between the pixel electrodes and the opposing electrodes is 0, projections of directors of liquid crystal molecules in the liquid crystal layer on a plane of the liquid crystal layer are substantially parallel to each other and a projection of the refractive index anisotropic axis of the optical compensation layer on the plane of the liquid crystal layer is parallel to the projections of the directors on the plane of the liquid crystal layer, and, where an angle of the refractive index anisotropic axis of the optical compensation layer with respect to the plane of the liquid crystal layer is represented by θ_F and angles between the directors and the plane of the liquid crystal layer on interfaces between the liquid crystal layer and the insulating substrates are represented by θ_1 and θ_2, θ_1 and θ_2 being different from each other, the angle θ_F satisfies $\theta_1 < \theta_F < \theta_2$ or $\theta_2 < \theta_F < \theta_1$, and the refractive index anisotropic axis of the optical compensation layer is parallel to the director of at least

one of the liquid crystal molecules in the liquid crystal layer.

Further preferably, the active matrix liquid crystal display panel is constructed such that, when a potential difference between the pixel electrodes and the opposing electrodes is 0, projections of directors of liquid crystal molecules in the liquid crystal layer on a plane of the liquid crystal layer are substantially parallel to each other and a projection of the refractive index anisotropic axis of the optical compensation layer on the plane of the liquid crystal layer is parallel to the projections of the directors on the plane of the liquid crystal layer, and, where an angle of the refractive index anisotropic axis of the optical compensation layer with respect to the plane of the liquid crystal layer is represented by θ_F and angles between the directors and the plane of the liquid crystal layer on interfaces between the liquid crystal layer and the insulating substrates are represented by θ_1 and θ_2, θ_1 and θ_2 being different from each other, the angle θ_F always satisfies $\theta_1 < \theta_F < \theta_2$ or $\theta_2 < \theta_F < \theta_1$, and the angle θ_F varies in a thicknesswise direction of the optical compensation layer in a corresponding relationship to a variation of the director in the thicknesswise direction of the liquid crystal layer.

[The embodiments of the invention]

Next, the embodiments of the invention are explained with reference to the drawings.

FIG. 1 is a sectional view showing a principal portion of the first embodiment of the active matrix liquid crystal display panel of the present invention, and FIG. 2 is a plan view of an active matrix substrate A of the active matrix liquid crystal display panel. The active matrix substrate A of the IPS system (in the present embodiment, on the light incoming side) is described. A plurality of opposing electrodes 2 connected to each other by an opposing electrode bus line 12 and a scanning line 14 are formed on a glass substrate (transparent insulating substrate) 6, and a gate insulating film 9 is formed in such a manner as to cover over the opposing electrodes 2 and the scanning line 14. Further, island-shaped amorphous silicon 13 which makes part of a thin film transistor (hereinafter referred to simply as "TFT"), which is an active element, a plurality of pixel electrodes 3 and a signal line 1 are formed on the gate insulating film 11. The pixel electrodes 3 and the signal line 1 extend in parallel to the opposing electrodes 2. Further, a protective insulating film 8 and an orientation film 11 are formed in a layered relationship. The source electrode of the TFT is connected to the pixel electrodes 3 while the drain electrode is connected to the signal line 1, and the scanning line 14 serves as the gate electrode of the TFT. The active matrix substrate A of the IPS system having the TFT is formed in this manner. It is to be noted that details of the method of production are hereinafter described.

A color filter substrate C (in the present embodiment,

on the light outgoing side) includes an orientation film 26 same as that on the active matrix substrate A side and provided on one of the two surfaces of another glass substrate (transparent insulating substrate) 6, and an optical compensation layer 5 formed from a plastic film and provided on the other surface of the glass substrate 10.

The active matrix substrate A and the color filter substrate C are disposed such that the orientation films thereof are opposed to each other, and a pair of polarizing plates are disposed on the outer sides of the two substrates while a liquid crystal layer 7 having a positive refractive index anisotropy is provided between the orientation films 11 of the two substrates. It is to be noted that the polarizing plate on the light incoming side serves as a polarizing plate 10 and the polarizing plate on the light outgoing side serves as an analyzer 4.

FIG. 3 illustrates the relationship among a polarization direction 18 of the polarizer, a polarization direction 16 of the analyzer, a director direction 21 of a liquid crystal molecule, a direction 47 of the refractive index anisotropy axis of the optical compensation layer, a substrate normal 19, a longitudinal direction 20 of the electrodes and a direction 22 of an electric field. The substrate normal 19, the longitudinal direction 20 of the electrodes and the direction 22 of the electric field expend perpendicularly to each other. Each broken line in FIG. 3 represents the polarization direction 18 of the polarizer. The polarization

direction 18 extends in parallel to a substrate plane 23 and defines a fixed angle with respect to the longitudinal direction 20 of the electrodes. The polarization direction 16 of the analyzer is perpendicular to the polarization direction 18 of the polarizer.

Liquid crystal molecules are oriented uniformly by the orientation film 11, and the directors 21 (longitudinal directions) thereof are inclined by a fixed angle (pretilt angle) with respect to the substrate plane 23. The pretilt angle normally ranges approximately from 1 to 10 degrees. Projections of the directors 21 of the liquid crystal molecules on the substrate plane 23 extend in parallel to the polarization direction 18 of the polarizer, and the refractive index anisotropic axis 17 of the optical compensation layer extends in parallel to the directors 21. The polarization direction 16 of the analyzer extends perpendicularly to the polarization direction 18 of the polarizer and in parallel to the substrate plane 23.

Some of conventional active matrix liquid crystal display panels of the transverse electric field type are controlled based on the following theory. In particular, where the potential difference between a pixel electrode and an opposing electrode is 0 (when no electric field is applied), light is absorbed by the polarizer and the analyzer and black is displayed. However, if an electric field is applied, then the directors are turned, and as the potential difference increases, the directors 21 are further turned. Consequently,

components which are not absorbed by the analyzer increase in a ray which has passed through the liquid crystal layer and the transmission factor increases, approaching a white display. Then, when the directors 51 are turned approximately by 45 degrees, the transmission factor (brightness) exhibits a maximum value.

Conventionally, however, even if control is performed based on this theory, it sometimes occurs that the display does not look well. As described above, when a substrate is viewed obliquely, principally from the fact that linearly polarized light after passing through the polarizing plates 10 undergoes, when it passes through the liquid crystal layer 7, a retardation so that it is converted into elliptically polarized light, even when no electric field is applied and the liquid crystal molecules are not turned, light sometimes comes into the analyzer 4 from the liquid crystal layer 7 while it includes polarized light components which cannot be absorbed by the analyzer 4. According to a result of detailed numerical calculation with the relationship between the direction of the pretilt angle and the direction of the ray taken into consideration, when viewed from a direction 24 (refer to FIG. 3), the transmission factor is very high comparing with that where the liquid crystal layer 7 is not present and only the polarizing plates of a cross nicol are viewed from the same direction 24. In other words, where black is to be displayed, it looks rather white and this deteriorates the display quality.

Therefore, in the present invention, the optical compensation layer 5 is provided. In the present embodiment, the optical compensation layer 5 which has a negative one axis refractive index anisotropy is provided between the glass substrate 6 and the analyzer 4, and the refractive index anisotropic axis 17 thereof extends in parallel to the directors 21 of the liquid crystal while the optical main axis in the liquid crystal layer 7 and the optical main axis in the optical compensation layer 5 extend in a substantially same direction, as shown in FIG.3. When light passes through the liquid crystal layer 7, it undergoes distortion of the polarization plane thereof by a retardation, and the polarization plane distorted in this manner is compensated for by the optical compensation layer 5 so that the polarization condition of the light approaches the polarization condition (linear polarization) at the time immediately after the light passes through the polarizer 10. Then, after the light passes through the optical compensation layer 5, it is absorbed by the analyzer 4 so that black is displayed. In this manner, the present invention exhibits an effect in that white floating in a black display can be suppressed by canceling a retardation which occurs in the liquid crystal layer 7 when black is to be displayed by means of the optical compensation layer 5 irrespective of the incoming direction of the ray. Besides, little influence is had on any other visibility angle characteristic than this. Accordingly, a liquid crystal display panel which has a very

wide visibility angle characteristic can be obtained.

As described above, since the direction 17 of the optical axis (refractive index anisotropic axis) of the optical compensation layer 5 is the same as the direction (direction of directors) 21 of the optical axis of the liquid crystal layer 7, at whichever angle light comes in, the optical main axis of the light when the light passes through the liquid crystal layer 7 and the optical main axis of the light when the light passes through the optical compensation layer 5 are substantially same as each other, and the liquid crystal layer 7 having a positive refractive index anisotropy and the optical compensation layer 5 having a negative refractive index anisotropy can be canceled effectively. Further, even if the optical compensation layer 5 which has a refractive index anisotropic axis in this direction is present, the transmission factor when the liquid crystal display panel is viewed from the front is not varied by it at all and also the visibility angle characteristics of white and half tones other than the black level are varied little. Accordingly, white floating of a black display can be prevented efficiently and gradation reversal can be prevented, and a better visibility angle characteristic can be achieved.

The distortion of the polarization plane of the light when the light passes through the liquid crystal layer 7 is composed of a retardation which increases in proportion to the product of the refractive index difference between the optical main axes and the optical path lengths. In order to correct the

distortion, a retardation in the opposite direction should be applied by the optical compensation layer 5. If the refraction indices of the liquid crystal layer 7 and the optical compensation layer 5 with regard to ordinary light are substantially equal to each other, then the ratios between the layer thicknesses and the optical path lengths are substantially equal to each other. Further, since the anisotropic axes of the refractive indices are common to each other and also the main axes upon passage of the ray are substantially same as each other, also the refractive index difference between the optical main axes and the refractive index anisotropies of the individual layers increase in proportion to each other. From the foregoing, by making the product $\Delta nL_C \cdot dL_C$ of the refractive index anisotropy ΔnL_C and the liquid crystal layer 7 , thickness dL_C of the liquid crystal layer 7 and the product $\Delta n_F \cdot d_F$ of the refractive index anisotropy Δn_F and the layer thickness d_F of the optical compensation layer 5 substantially coincide with other, the distortion (retardation) of the polarization plane produced in the liquid crystal layer can be corrected substantially fully by the optical compensation layer, white floating can be suppressed to a level substantially equal to that obtained where only the cross Nicol is used.

It is to be noted that, as described above, in order to achieve more complete compensation, the refractive index of the liquid crystal layer 7 for ordinary light and the

refractive index of the optical compensation layer 5 for ordinary light are preferably set equal to each other. Where the refractive indices of them are different from each other, a ray passes in finely different directions through the layers, resulting in fine differences of the directions of the optical main axes, the refractive index differences on the main axes and the optical path lengths, and consequently, complete compensation cannot be achieved. However, if the refractive indices of them are made coincide with each other, then the optical main axes coincide completely with each other, and compensation of retardations of the liquid crystal layer 7 and the optical compensation layer 5 can be achieved more completely.

A relationship of the zenithal angle 25 and the transmission factor in the active matrix liquid crystal display panel when a substrate is actually viewed from a direction of the azimuth of 45 degrees with reference to the direction of the polarization axis 18 of the polarizer as shown in FIG. 3 is illustrated in FIG. 4. While, where the optical compensation layer 5 is absent, the transmission factor exhibits a reversal at the small zenithal angle 25 of approximately 35 degrees as seen in FIG. 15, by employing the optical compensation layer 5, the zenithal angle 25 at which the transmission factor exhibits a reversal can be driven to a range higher by 10 degrees or more, and also the brightness when a transmission factor reversal occurs can be suppressed to a considerably low level.

A decrease of the white brightness of an electric field applied portion of the active matrix liquid crystal display panel when it is viewed from an oblique direction where the optical compensation layer 5 is absent is illustrated in FIG. 5, and a decrease of the white brightness of an electric field applied portion of the active matrix liquid crystal display panel when it is viewed from an oblique direction where the optical compensation layer 5 is provided is illustrated in FIG. 6. From FIGS. 5 and 6, it can be seen that, with the liquid crystal display panel which includes the optical compensation layer 5, the decrease of the white brightness is suppressed smaller than that with the panel which does not include an optical compensation layer, and deterioration of the display quality is suppressed low at both of a black display portion and a white display portion by the action of the optical compensation layer 5.

An example of a method of producing a liquid crystal display panel having such a construction as described above is described in detail.

First, a method of producing the active matrix substrate A is described.

As a metal layer from which the scanning lines 14, opposing electrodes 2 and opposing electrode bus lines 12 are to be produced, a Cr film is layered with 150 nm on a transparent glass substrate and then patterned. Further, as the gate insulating film 9, a silicon nitride film of 400 nm thick, a non-doped amorphous silicon film of 350 nm thick and an

n-type amorphous silicon film of 30 nm thick are successively layered. Thereafter, the n-type amorphous silicon layer and the non-doped amorphous silicon layer are patterned to form island-shaped amorphous silicon 13. Then, as a metal layer from which the signal lines 1 and the pixel electrodes 3 are to be formed, a Cr film is layered with 150 nm and then patterned. Further, the protective insulating film 8 is formed and then removed at peripheral terminal portions thereof, thereby completing a TFT.

To the active matrix substrate A produced in such a manner as described above and a color filter substrate C, the orientation films 11 and 26 are applied, respectively. The orientation film 11 on the active matrix substrate side is rubbed in the direction 15 in FIG. 1, and the orientation film 26 on the color filter substrate side is rubbed in the opposite direction to the direction 15 in FIG. 1. The two substrates are disposed such that the two orientation films 23 oppose each other and are secured to each other at peripheral portions thereof by a seal member (not shown). Thereafter, liquid crystal is injected into and enclosed in a gap between the two orientation films to provide the liquid crystal layer 7. It is to be noted that the liquid crystal directors 21 are oriented substantially in a fixed direction in the liquid crystal layer 7 by the orientation films 11 and 26. The pretilt angle between the liquid crystal directors 21 and the substrate plane 5

23 in the present embodiment is 3 degrees. The refractive

index of the injected liquid crystal for ordinary light is no = 1.476 and the refractive index anisotropy is $\Delta n = 0.067$, and in order to optimize the brightness of a white display and the color reproduction property, the cell gap was set to 4.5 μm.

Further, a plastic film to serve as the optical compensation layer 5 is applied to the outer side of the color filter substrate. The optical compensation layer 5 has a negative one axial refractive index factor anisotropy, and the refractive index anisotropic axis extends in a direction parallel to the initial orientation direction of the liquid crystal directors 21, that is, in a direction in which it defines 3 degrees with respect to the plane of the substrate. The product $\Delta n_F \cdot d_F$ of the refractive index anisotropy Δn_F and the layer thickness d_F of the optical compensation layer was set equal to the product of the refractive index anisotropy and the layer thickness of the liquid crystal layer and 302 nm.

Two polarizing plates are applied such that the active matrix substrate A and the color filter substrate C are held between them. In this instance, the polarization axis 18 of the polarizer (light incoming side polarizing plate) 10 extends in parallel to the rubbing direction 15 while the polarization axis of the analyzer (light outgoing side polarizing plate) 4 extends in a direction perpendicular to the direction of the polarization axis 18.

The liquid crystal display panel produced in this manner was driven actually. It was revealed that a good display characteristic wherein the black level was stabilized over a visibility angle range wider than ever and little gradation reversal was found was obtained successfully, and the liquid crystal display panel was able to be used over a visibility angle range of 50 degrees in the upward and downward directions and the leftward and rightward directions.

Next, the second embodiment of the present invention is described in detail with reference to the drawings.

The active matrix liquid crystal display panel of the present embodiment has an almost same construction and is produced by an almost same production method as the first embodiment, but is different from the first embodiment in the orientation directions of two orientation films 27 and 28 and the angle defined between the directors of liquid crystal molecule and the plane of a substrate.

FIG.7 is a sectional view showing a section of the liquid crystal display panel taken along a plane including the polarization axis of the polarizer and a substrate normal line in order to show a direction 29 of the directors of liquid crystal molecules and a direction 31 of the refractive index anisotropic axis of an optical compensation layer 30. Here, the signal lines 1, scanning lines 14, island-shaped amorphous silicon 13, pixel electrodes 3, opposing electrodes, polarization direction 18 of the polarizer, polarization direction 16 of the analyzer and so forth have same

constructions as those of the first embodiment (refer to FIGS. 1 to 3).

The orientation films 27 and 28 are subject to orientation processing (rubbing) in the same direction (same direction as the direction 15 of FIG. 2). The direction 29 of the directors liquid crystal molecules vary in a liquid crystal layer 32. While projections of the directors of all liquid crystal molecules on the plane of the substrate extend in the same direction parallel to the polarization direction 18 of the polarizer, the angle defined between the directors 29 of liquid crystal molecules and the plane of the substrate is different between that on the light incoming side substrate interface and that on the light outgoing side substrate interface. Where the angles are represented by θ_1 and θ_2, respectively, the angle θL_C of the directors with respect to the plane of the substrate continuously varies between the two interfaces and is distributed so as to minimize the strain energy.

The optical compensation layer 30 formed from a plastic film applied to the outer side of the color filter substrate C has a negative one axis refractive index anisotropy, and the direction 31 of the refractive index anisotropic axis is set such that a projection thereof on the plane of the substrate extends in parallel to projections of the polarization axis 18 of the polarizer and the directors 29 of liquid crystal molecules on the plane of the substrate. Further, the angle θ_F defined between the anisotropic axis

31 of the optical compensation layer and the plane of the substrate is uniform in the inside of the layer and $\theta_2 < \theta_F < \theta_1$ and 0.45 degrees in the present embodiment. It is to be noted that, otherwise if $\theta_1 < \theta_2$, then the angle θ_F is set so as to satisfy $\theta_1 < \theta_F < \theta_2$. The material of the liquid crystal and the cell thickness are same as those of the first embodiment, and the product $\Delta n_F \cdot d_F$ between the refractive index anisotropy Δn_F and the layer thickness d_F of the optical compensation layer is equal to the product of the refractive index anisotropy and the layer thickness of the liquid crystal layer 32 and 302 nm in the present embodiment.

The polarization axis 18 of the polarizer 10 from between the two polarizing plates applied to the outer sides of the liquid crystal display panel extends in parallel to the rubbing direction 15, and the polarization axis of the analyzer 4 extends in a direction perpendicular to the rubbing direction 15 (refer to FIG. 2).

In the present embodiment, an optimum value of θ_F can be determined by simulation or experiment although this is not very simple because the optical main axis in the liquid crystal layer varies in the thicknesswise direction. Conveniently, the optimum value of θ_F may be given as $\theta_F = (\theta_1 + \theta_2)/2$. Where the optimum value of θ_F is used, the retardation of the liquid crystal layer 32 and the retardation of the optical compensation layer 30 when black is to be

displayed cancel each other considerably well, and white floating in a black display can be suppressed to such a degree as that of a cross nicol.

The active matrix liquid crystal display panel which was produced in such a manner as described above had a very wide visibility angle characteristic similarly as in the first embodiment.

It is to be noted that, in order to obtain a good black display, projections of the directors of liquid crystal molecules on the plane of the substrate are normally held substantially in coincidence with the polarization axis of a polarizing plate on one side. Then, also a projection of the refractive index anisotropic axis of the optical compensation layer 30 on the plane of the substrate is set to the same direction. Further, the angle θ_F defined between the refractive index anisotropic axis of the optical compensation layer and the plane of the substrate can be set to a suitable position between θ_1 and θ_2 so that white floating can be suppressed efficiently.

Next, the third embodiment of the present invention is described in detail with reference to the drawings.

The active matrix liquid crystal display panel of the present embodiment has an almost same construction and is produced by an almost same production method as the second embodiment, but is different from the second embodiment in the angle defined between an optical compensation layer 33 and the plane of a substrate.

FIG. 8 is a sectional view showing a section of the liquid crystal display panel taken along a plane including the polarization axis of the polarizer 10 and a substrate normal line in order to show a direction 34 of the directors of liquid crystal molecules and a direction 35 of the refractive index anisotropic axis of the optical compensation layer 33. Here, the signal lines 1, scanning lines 14, island-shaped amorphous silicon 13, pixel electrodes 3, opposing electrodes 2, polarization direction 18 of the polarizer, polarization direction 16 of the analyzer and so forth have same constructions as those of the fourth embodiment (refer to FIGS. 1 to 3).

Similarly as in the fifth embodiment, the two orientation films 27 and 28 are subject to orientation processing (rubbing) in the same direction (same direction as the direction 15 of FIG. 2). The direction of the directors 34 of liquid crystal molecules varies in a liquid crystal layer 36. While projections of the directors of all liquid crystal molecules on the plane of the substrate extend in the same direction parallel to the polarization direction 18 of the polarizer 10, the angle defined between the directors of liquid crystal molecules and the plane of the substrate is different between that on the light incoming side substrate interface and that on the light outgoing side substrate interface. Where the angles are represented by θ_1 and θ_2, respectively, the angle $\theta_{LC}(z)$ of the directors with respect to the plane of the substrate continuously varies between the

two interfaces and is distributed so as to minimize the strain energy.

The polarization axis of the light incoming side one (polarizer) 10 of the two polarizing plates adhered in such a manner that the two substrates are held between them extends in parallel to the rubbing direction 15 (refer to FIG. 2), and the polarization axis of the light outgoing side polarizing plate (analyzer) 4 extends in a direction perpendicular to the rubbing direction 15 (refer to FIG. 2).

The optical compensation layer 33 has a negative one axis refractive index anisotropy and is set such that a projection of the refractive index anisotropic axis on the plane of the substrate always extends in parallel to projections of the polarization direction 18 of the polarizer and the directors of liquid crystal molecules on the plane of the substrate. Further, as seen in FIG. 8, the angle defined between the refractive index anisotropic axis 35 of the optical compensation layer and the plane of the substrate varies in the inside of the layer, and this angle is a function $\theta_F(\xi)$ of the coordinate ξ in the depthwise direction. $\theta_{LC}(z)$ and $\theta_F(\xi)$ are set so as to satisfy the following relations:

$$\theta F(\xi) = \theta_{LC}(z)$$

$$\xi = z \cdot d_F/d_{LC}$$

where d_F is the thickness of the optical compensation layer, d_{LC} the thickness of the liquid crystal layer, and $\theta_{LC}(z)$ the

angle defined between the directors of liquid crystal molecules at the position of the depth z in the liquid crystal layer 36 and the plane of the substrate.

$\theta_{LC}(z)$ is distributed in accordance with the following expression:

$$\theta_{LC}(z) = \theta_1 - \theta_2 \cdot \frac{z}{d_{LC}} + \theta_2$$

If the direction of the refractive index anisotropic axis of the optical compensation layer is varied so as to satisfy the relationship given above, slab surfaces corresponding to each other compensate for each other, and accordingly, the efficiency is high.

It is to be noted that the material of the liquid crystal and the cell thickness are same as those of the first embodiment, and the product $\Delta n_F \cdot d_F$ between the refractive index anisotropy Δn_F and the layer thickness d_F of the optical compensation layer is equal to the product of the refractive index anisotropy and the layer thickness of the liquid crystal layer and 302 nm in the present embodiment.

In the present embodiment, since the optical main axis in the liquid crystal layer varies in the thicknesswise direction z, by varying $\theta_F(\xi)$ in accordance with the variation, a further better visibility angle characteristic of a black display can be obtained comparing with the second embodiment.

In the three embodiments described above, an optical

compensation layer is provided between the analyzer 4 and a glass substrate 6. However, an optical compensation layer 37 may otherwise be held between the polarizer 5 and a glass substrate 6 as seen in FIG. 9. In this instance, almost similar effects can be obtained if the construction such as the direction of the refractive index anisotropic axis of the optical compensation layer 37 is the same as that in one of the three embodiments described above.

Meanwhile, a further construction may alternatively be employed wherein, as shown in FIG. 10, optical compensation layers 38 and 39 are provided both between the analyzer 34 and one of the glass substrates 6 and between the polarizer 10 and the other glass substrate 5. If the directions of the anisotropic axes of them are set parallel to each other and the sum of products of Δn and d of the two optical compensation layers is set equal to $\Delta n_{LC} \cdot d_{LC}$ of the liquid crystal layer 7, then almost complete compensation can be achieved.

Further, while, in the embodiments described above, projections of the polarization axis of the polarizer and the directors of liquid crystal molecules on the plane of a substrate are set parallel to each other, similar effects can be obtained even if projections of the polarization axis of the analyzer and the directors of the liquid crystal on the plane of the substrate are set parallel to each other and the polarization axis of the polarizer is set perpendicular to them.

[Effect of the invention]

As described above, according to the present invention, since an optical compensation layer having a negative one axis refractive index anisotropy in an active matrix liquid crystal display panel, a retardation produced in a liquid crystal layer can be canceled to suppress white floating of a black display portion and gradation reversal can be suppressed significantly, and an image characteristic which is good in a wider visibility angle can be obtained.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 is a sectional view of an active matrix liquid crystal display panel of the first embodiment of the present invention.

FIG. 2 is a plan view of an active matrix substrate in the first embodiment of the present invention.

FIG. 3 is a diagrammatic view illustrating a relationship among the polarization axis, the liquid crystal directors and an the refractive index anisotropic axis of an optical compensation layer in the first embodiment of the present invention.

FIG. 4 is a diagram illustrating a relationship between the zenithal angle and the transmission factor of the fourth embodiment when no voltage is applied or a low voltage is applied.

FIG. 5 is a diagram illustrating a relationship between the zenithal angle and the transmission factor of the first

embodiment when a high voltage is applied.

FIG. 6 is a diagram illustrating a relationship between the zenithal angle and the transmission factor of a conventional active matrix liquid crystal display panel of the IPS system when a high voltage is applied.

FIG. 7 is a sectional view of an active matrix liquid crystal display panel of the second embodiment.

FIG. 8 is a sectional view of an active matrix liquid crystal display panel of the third embodiment.

FIG. 9 is a sectional view of an active matrix liquid crystal display panel of the fourth embodiment.

FIG. 10 is a sectional view of an active matrix liquid crystal display panel of the fifth embodiment.

FIG. 11 is a diagrammatic view showing a construction of a conventional active matrix liquid crystal display panel of the IPS system and illustrating the relationship between a polarization axis and the direction of an electric field.

FIG. 12 is a diagram illustrating the relationship between the voltage and the transmission factor of a conventional active matrix liquid crystal display panel of the TN system.

FIG. 13 is a diagram showing a polarization axis, the direction of a ray, the azimuth and the zenithal angle of the conventional active matrix liquid crystal display panel of the IPS system.

FIG. 14 is a diagram illustrating relationships between the zenithal angle and the transmission factor at various

pretilt angles of the conventional active matrix liquid crystal display panel of the IPS system when no voltage is applied.

FIG. 15 is a diagram illustrating a relationship between the zenithal angle and the transmission factor of a conventional active matrix liquid crystal display panel of the IPS system wherein the pretilt angle is 3 degrees when a voltage is applied or no voltage is applied.

(The explanation of the signs)

1 signal line
2 opposing electrode
3 pixel electrode
4 analyzer (light outgoing side polarizing plate)
5,30,33,37,38,39 optical compensation layer
6 glass substrate (transparent insulating substrate)
7,32,36 liquid crystal layer
8 protective insulating film
9 gate insulating film
10 polarizer (light income side polarizing plate)
11,26,27,28 orientation film
12 opposing electrode bus line
13 island-shaped amorphous silicon
14 scanning line
15 liquid crystal orientation direction(rubbing direction)
16 polarizing direction of analyzer
17,31,35 direction of refractive index anisotropy axis
18 polarizing direction of polarizer
19 substrate normal
20 longitudinal direction of electrode
21,29,34 direction of liquid crystal molecule director
22 direction of electrode
23 substrate plane
24 direction of light

25 zenithal angle

26 orientation film

A active matrix substrate

C colour filter substrate

e_1 unit vector of polarization axis orientation of polarizer

e_2 unit vector of polarization axis orientation of analizer

e_3 unit vector of direction of substrate normal

k unit vector of advancing direction of light

α zenithal angle

ϕ azimuth

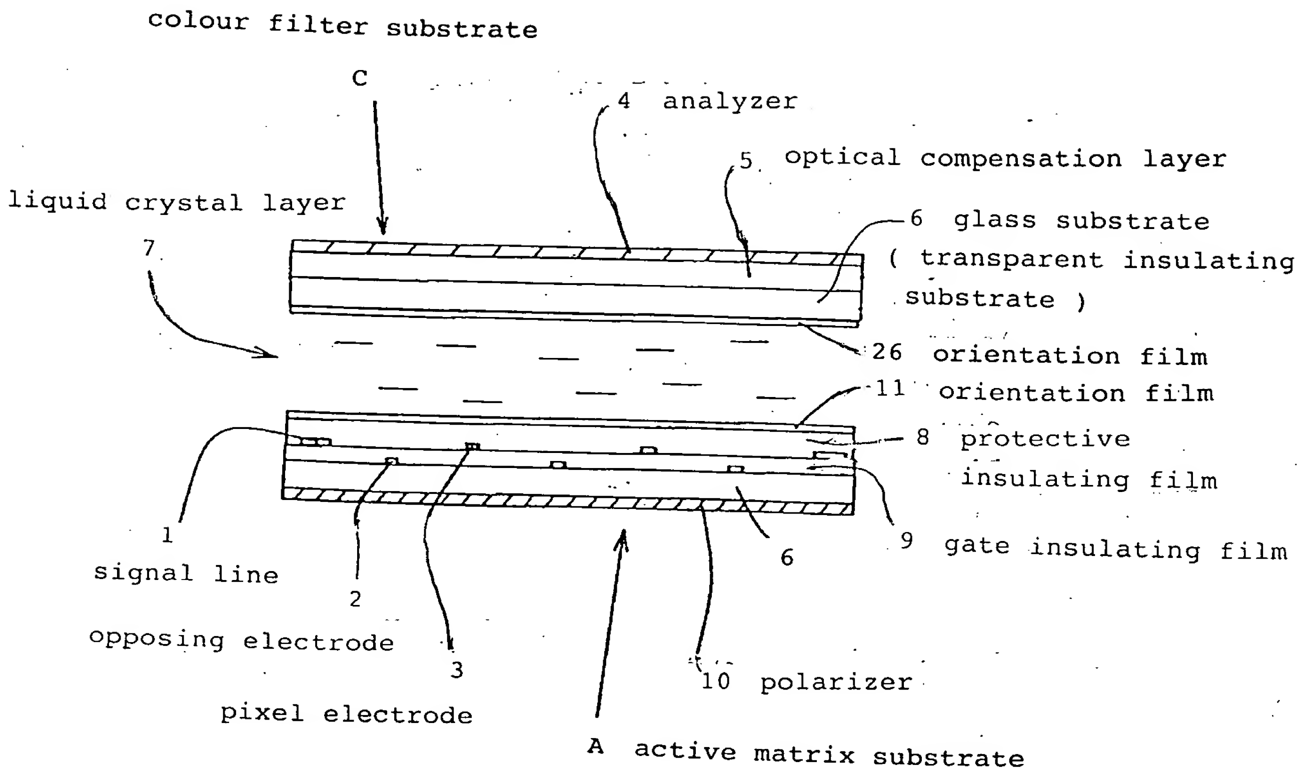
θ_1, θ_2 angle between liquid crystal director and substrate plane in substrate interface

θ_F, $\theta_F(\xi)$ angle between anisotropy axis of optical compensation layer and substrate plane

θ_{LC}, $\theta_{LC}(z)$ angle between liquid crystal director and substrate plane in liquid crystal layer

B

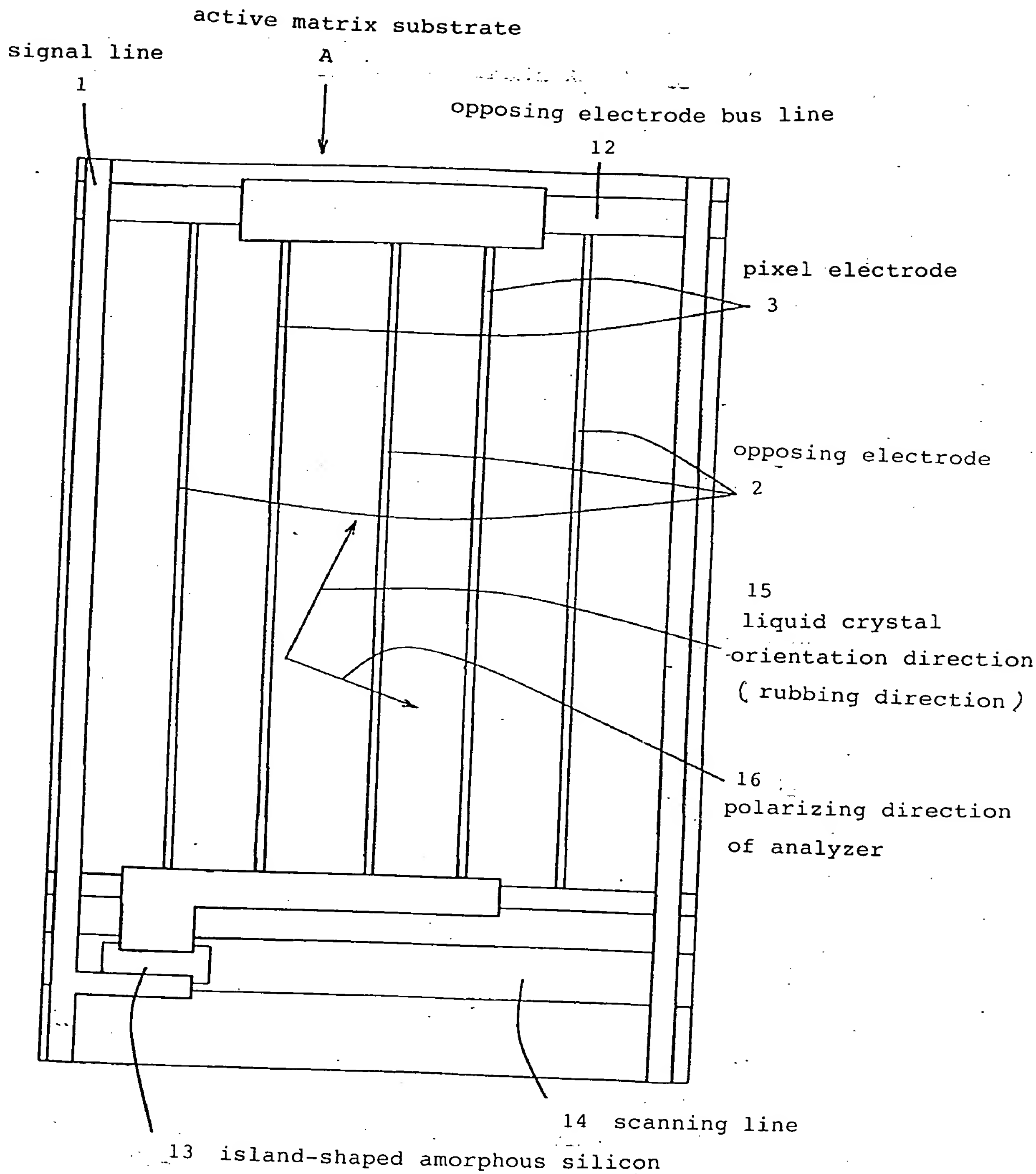
FIG. 1



colour filter substrate
C
4 analyzer
5 optical compensation layer
liquid crystal layer
7
6 glass substrate
(transparent insulating
substrate)
26 orientation film
11 orientation film
8 protective
insulating film
1
signal line
2
opposing electrode
3
pixel electrode
6
9 gate insulating film
10 polarizer
A active matrix substrate

B

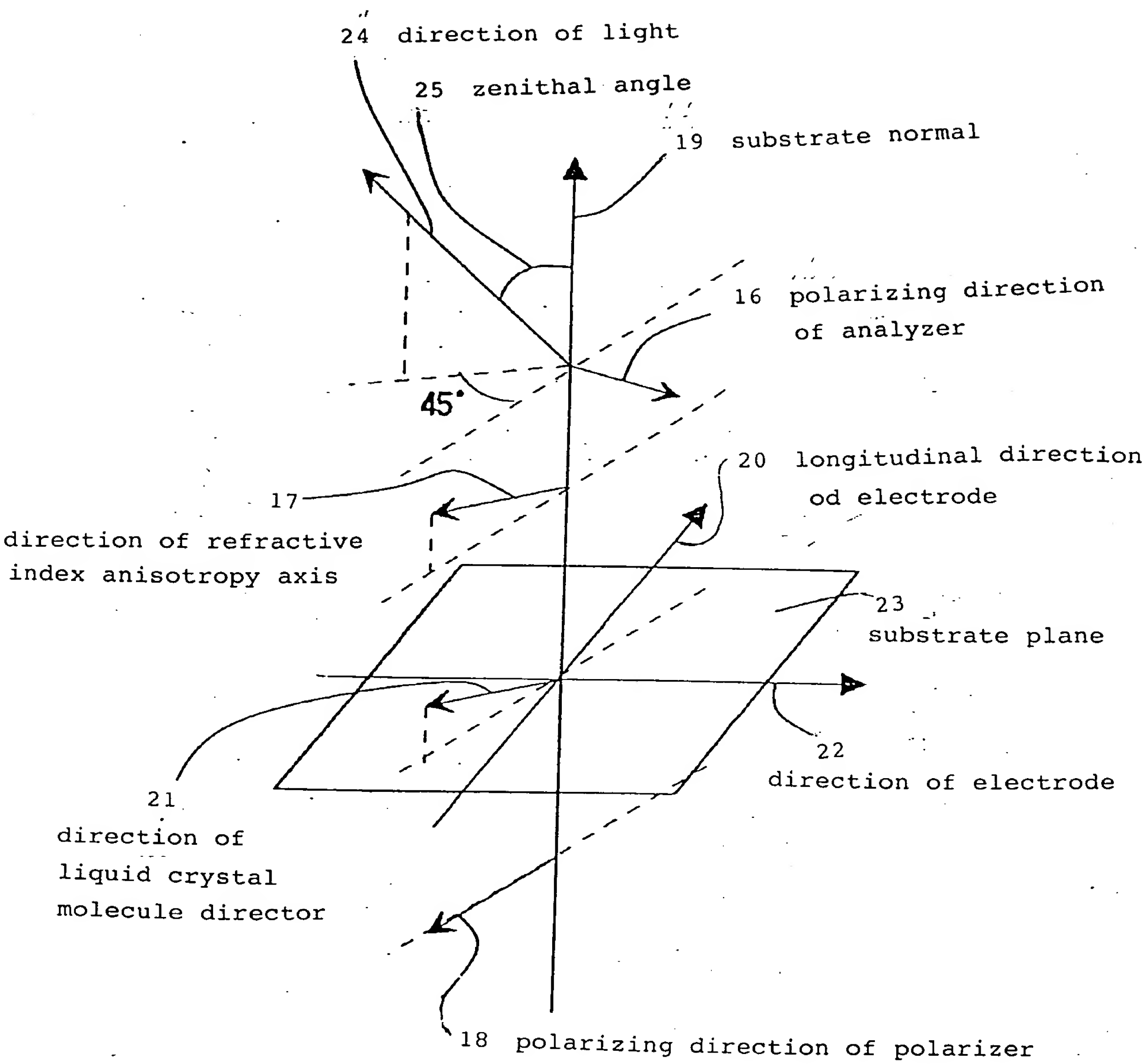
FIG. 2



active matrix substrate
A
signal line
1
opposing electrode bus line
12
pixel electrode
3
opposing electrode
2
15
liquid crystal
orientation direction
(rubbing direction)
16
polarizing direction
of analyzer
14 scanning line
13 island-shaped amorphous silicon

13

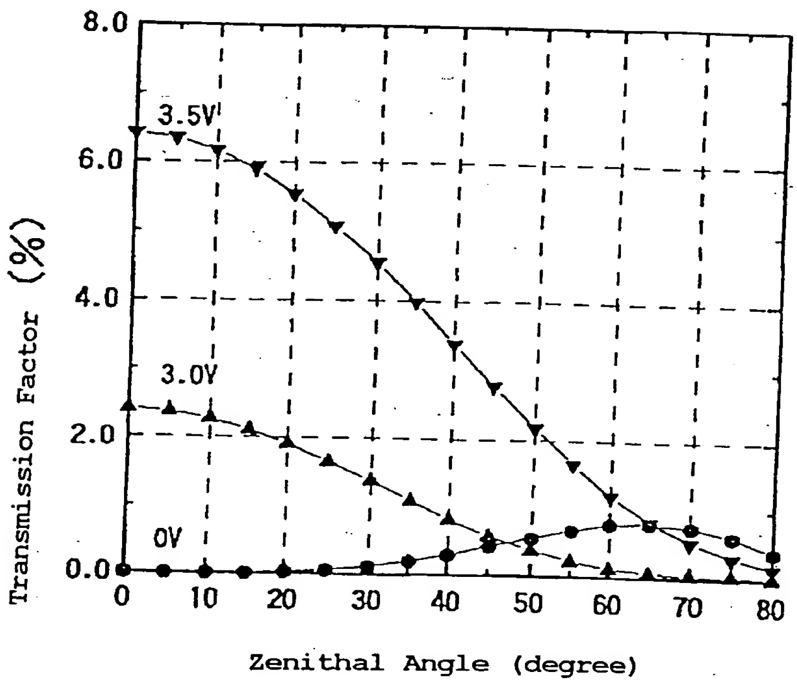
FIG. 3



24 direction of light
25 zenithal angle
19 substrate normal
16 polarizing direction of analyzer
45°
20 longitudinal direction od electrode
17
direction of refractive index anisotropy axis
23 substrate plane
22 direction of electrode
21 direction of liquid crystal molecule director
18 polarizing direction of polarizer

B

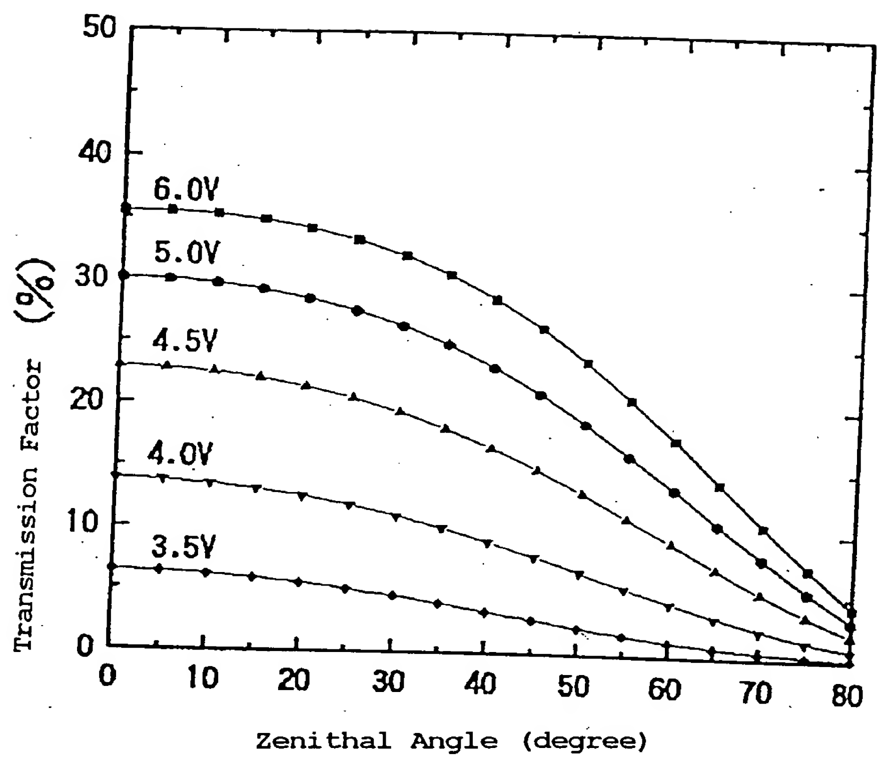
FIG. 4



8.0
6.0
4.0
2.0
0.0
3.5V
3.0V
0V
Transmission Factor (%)
0
10
20
30
40
50
60
70
80
Zenithal Angle (degree)

B

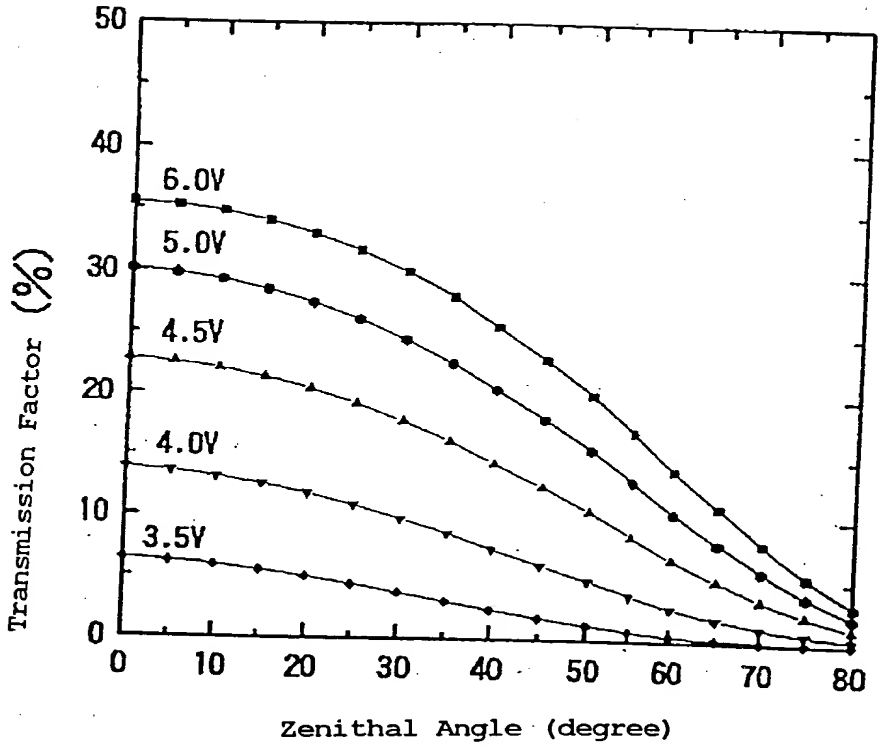
FIG. 5



6.0V
5.0V
4.5V
4.0V
3.5V
Transmission Factor (%)
0
10
20
30
40
50
0
10
20
30
40
50
60
70
80
Zenithal Angle (degree)

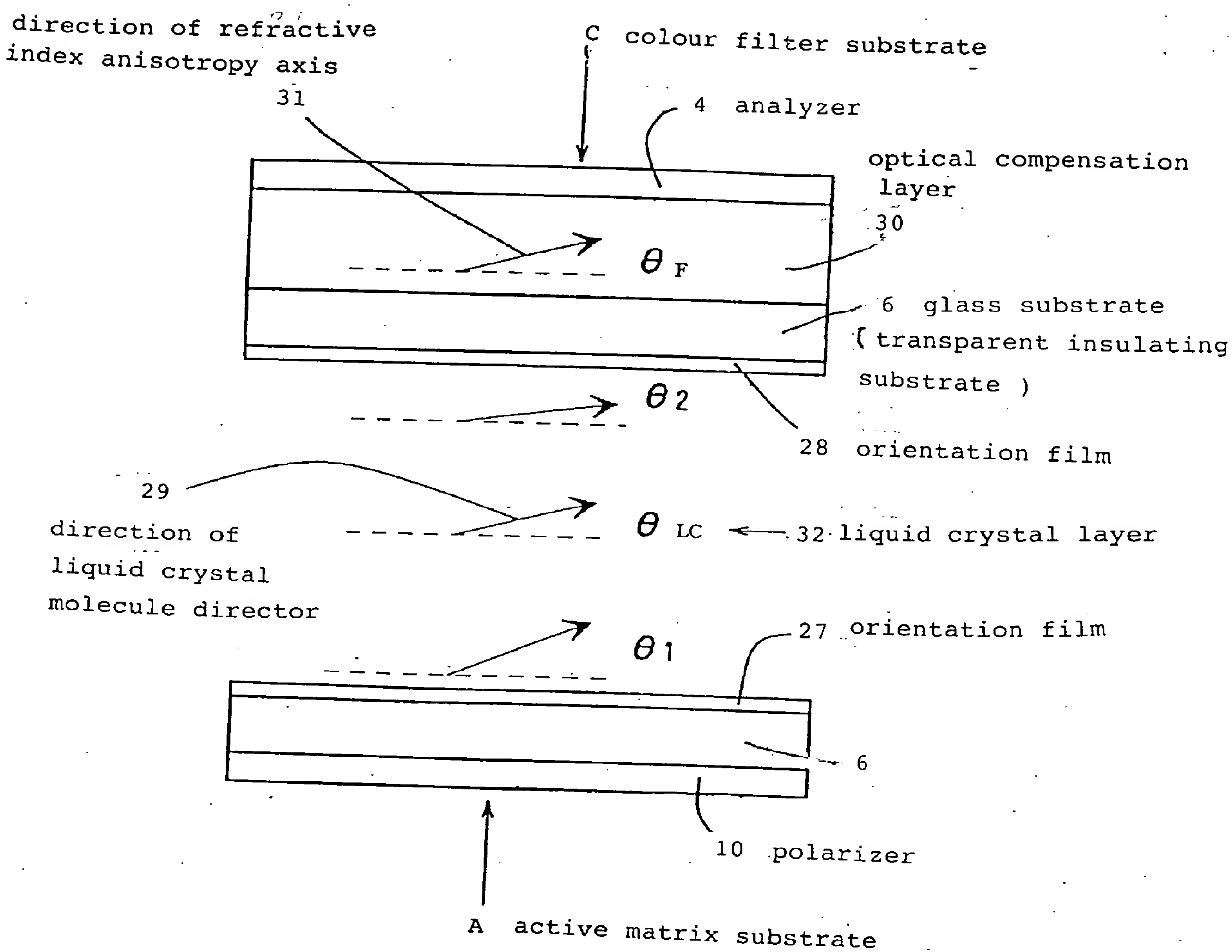
B

FIG. 6 PRIOR ART



B

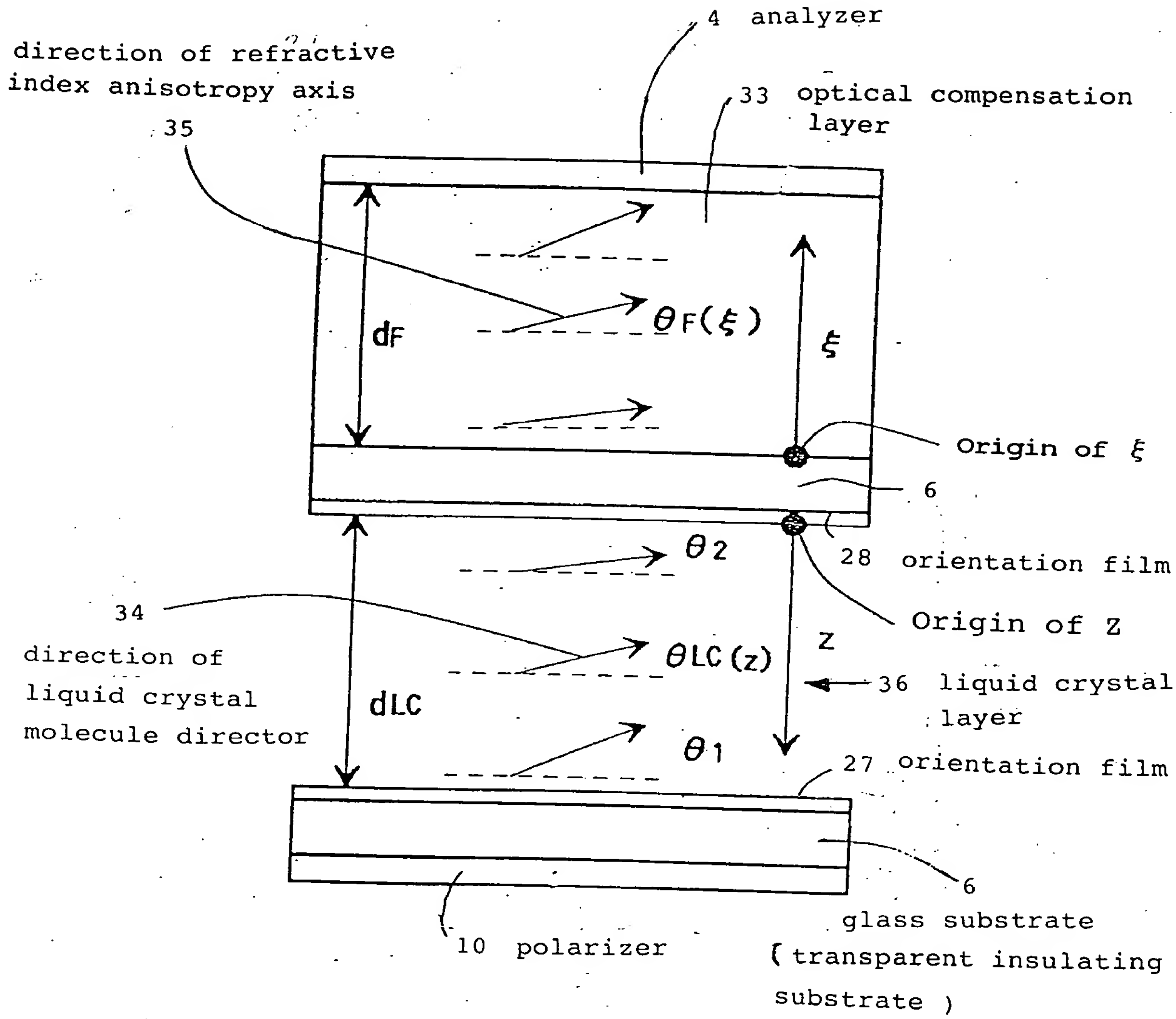
FIG. 7



direction of refractive index anisotropy axis
31
C colour filter substrate
4 analyzer
optical compensation layer
30
θ F
6 glass substrate (transparent insulating substrate)
θ 2
28 orientation film
29
direction of liquid crystal molecule director
θ LC
32 liquid crystal layer
θ 1
27 orientation film
6
10 polarizer
A active matrix substrate

E

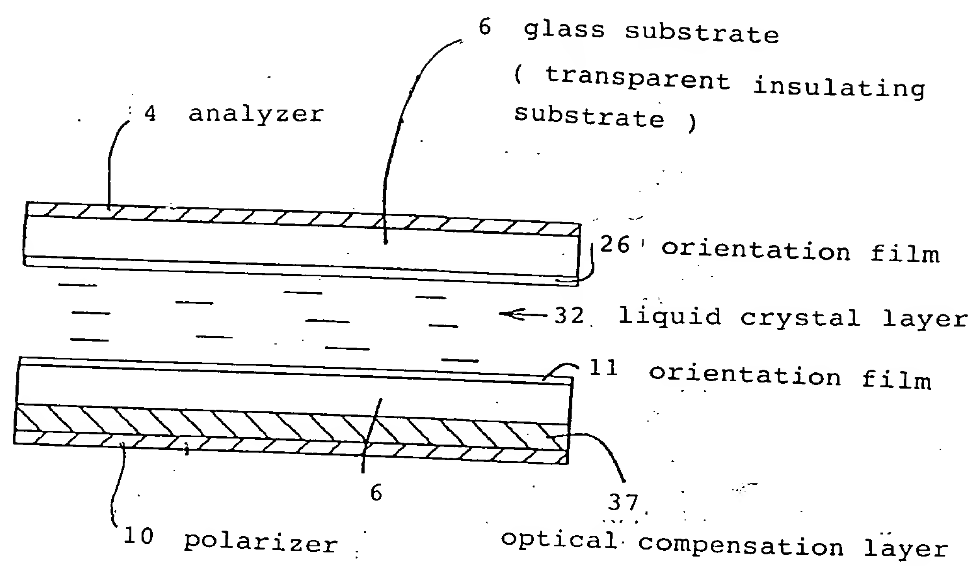
FIG. 8



4 analyzer
direction of refractive index anisotropy axis
33 optical compensation layer
35
dF
θF(ξ)
ξ
Origin of ξ
6
θ2
28 orientation film
34
Origin of Z
direction of liquid crystal molecule director
θLC(z)
z
36 liquid crystal layer
dLC
θ1
27 orientation film
6
glass substrate
(transparent insulating substrate)
10 polarizer

8

FIG. 9


6 glass substrate
(transparent insulating substrate)
4 analyzer
26 orientation film
32 liquid crystal layer
11 orientation film
6
37
10 polarizer
optical compensation layer

B

FIG. 10

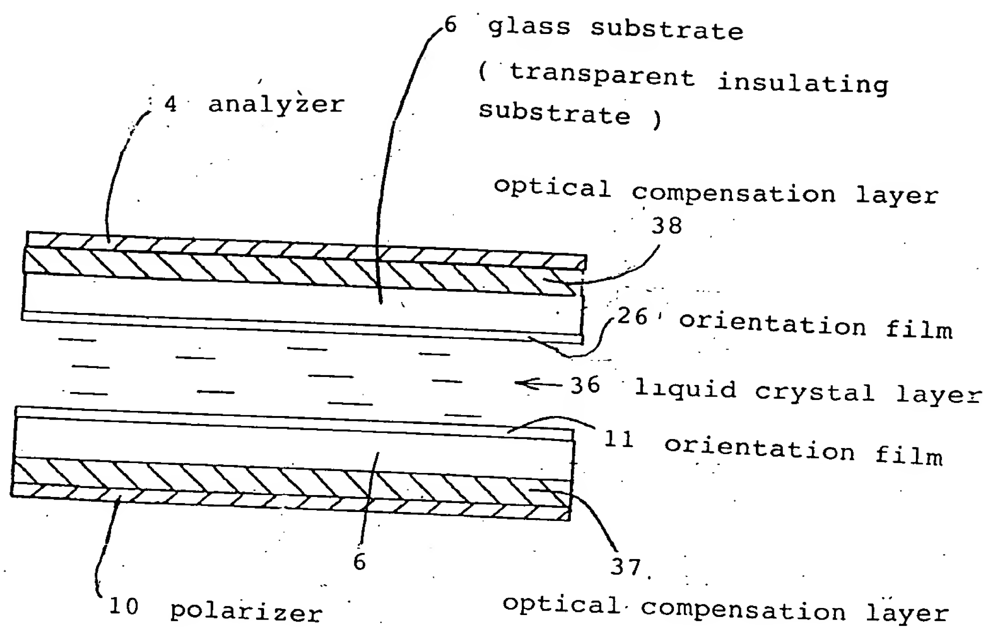
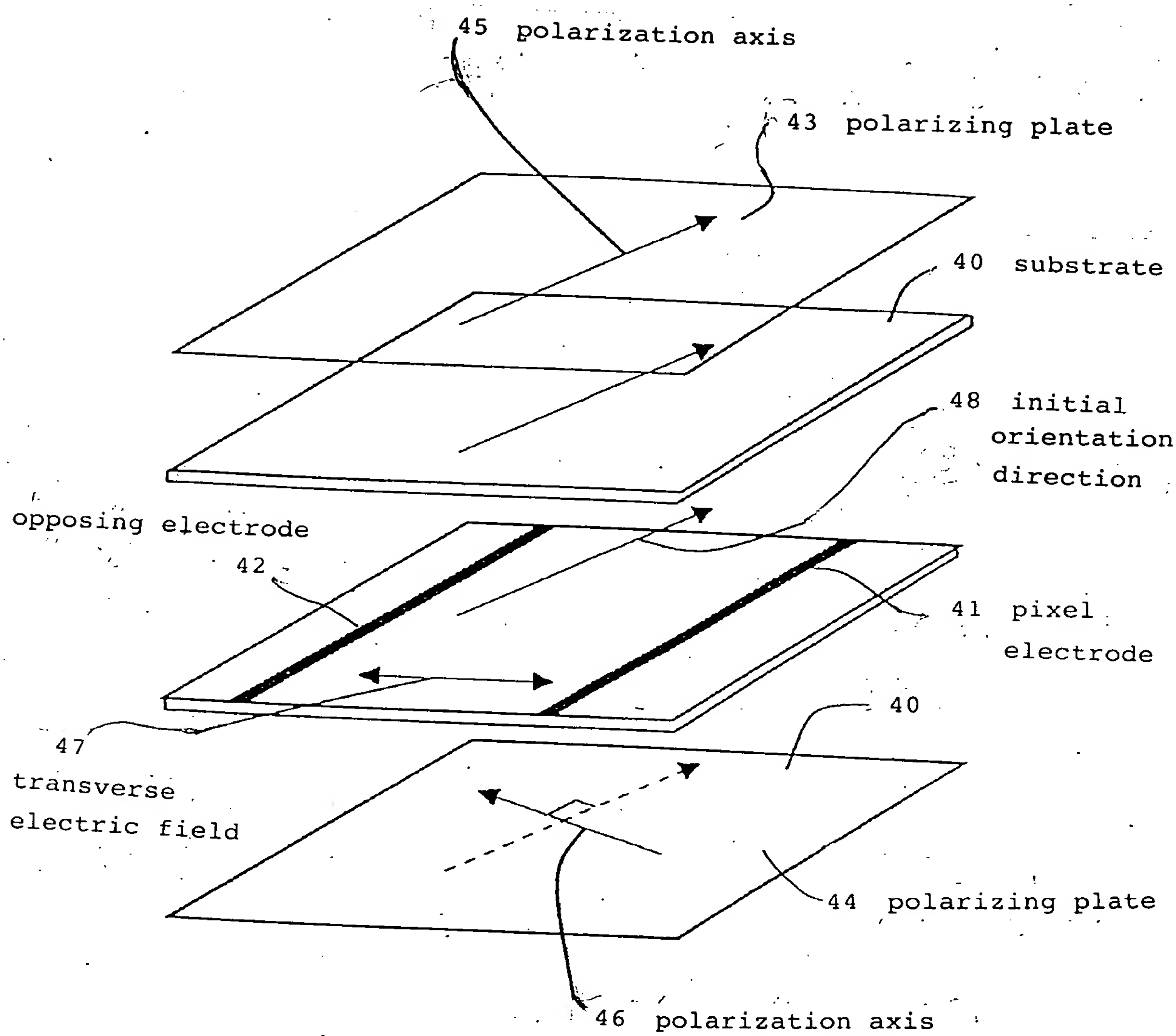
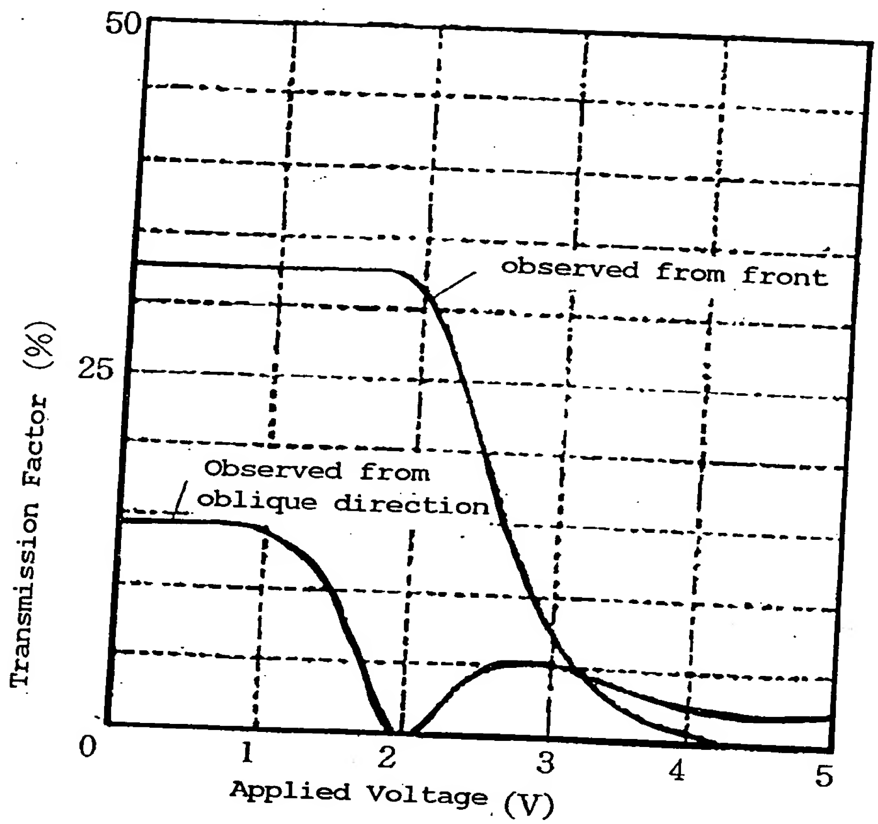

6 glass substrate
(transparent insulating substrate)
4 analyzer
optical compensation layer
38
26 orientation film
36 liquid crystal layer
11 orientation film
6
37
10 polarizer
optical compensation layer

FIG. 11 PRIOR ART



B

FIG. 12 PRIOR ART



B

FIG. 13 PRIOR ART

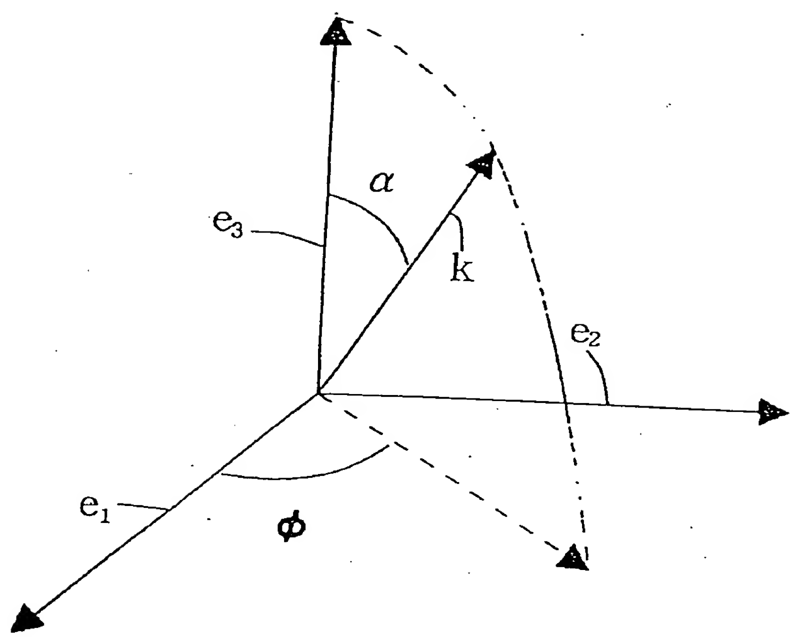


FIG. 14 PRIOR ART

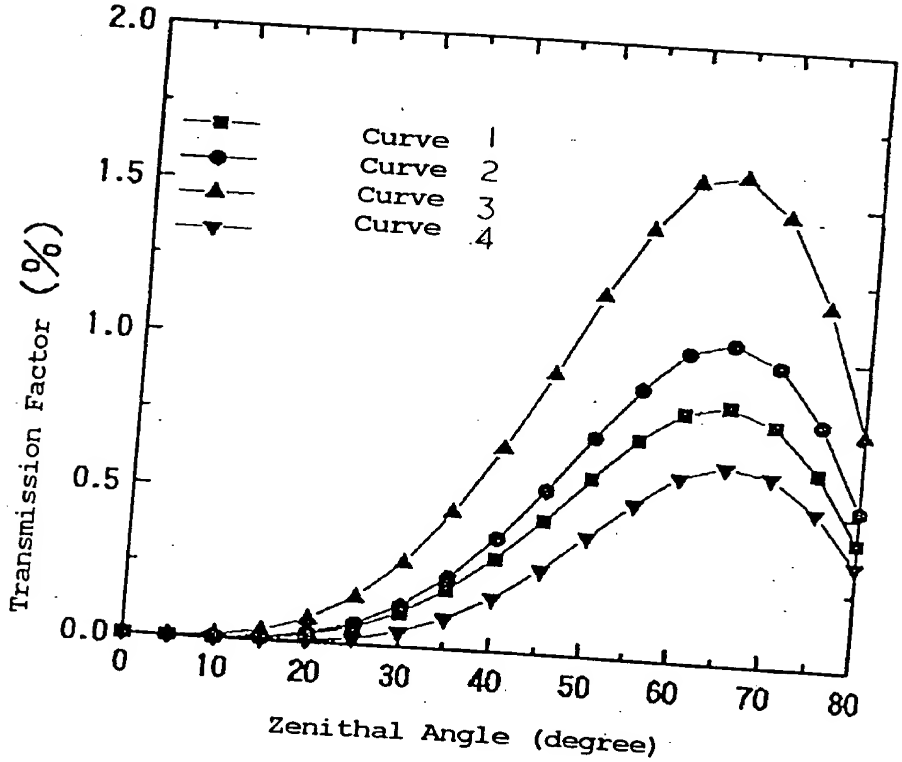
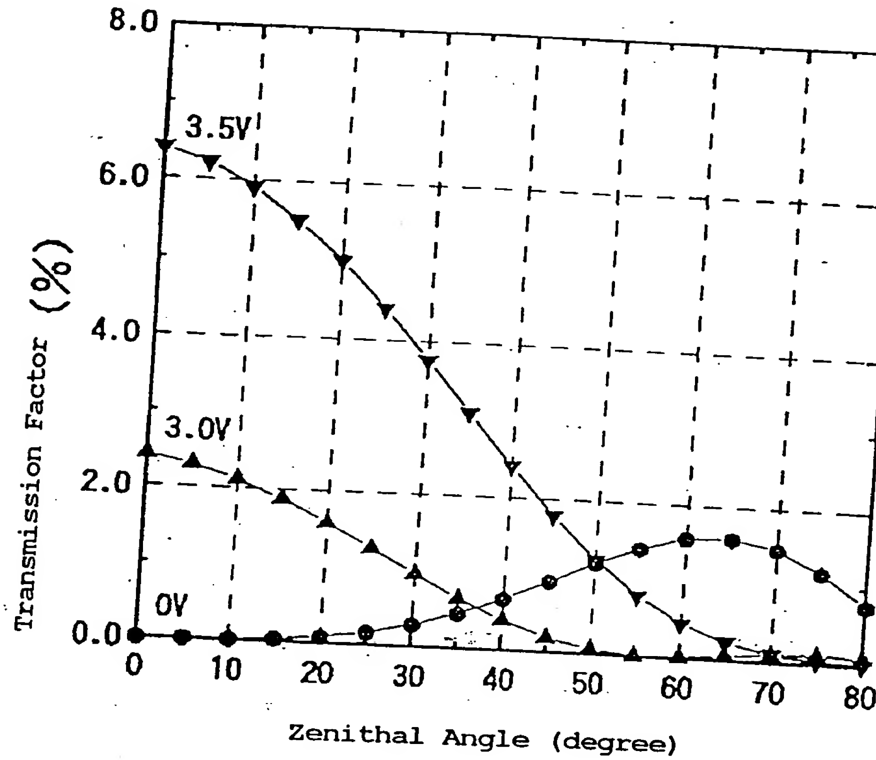


FIG. 15 PRIOR ART



ABSTRACT OF THE DISCLOSURE

[Problem] An active matrix liquid crystal display panel by which a good display characteristic can be obtained without suffering from gradation reversal over a wide visibility angle range.

[Means for solving] An active matrix substrate A includes a plurality of opposing electrodes 2, a plurality of pixel electrodes 3 parallel to the opposing electrodes 2, a thin film transistor, and an orientation film 11 all formed on a glass substrate 6. A color filter substrate C includes an orientation film 26 provided on one surface of another glass substrate 6 and an optical compensation layer 5 provided on the other surface of the glass substrate 6 and formed from a plastic film. The two substrates are disposed such that the orientation films thereof oppose each other, and polarization plates 4 and 11 are disposed on the outer sides of the two substrates, and a liquid crystal layer 7 having a positive refractive index anisotropy is provided between the orientation films 11. The optical compensation layer 5 has a negative one axial refractive index anisotropy and can cancel a retardation produced in the liquid crystal layer 7 thereby to suppress white floating of a black display portion.

[Selected drawing] FIG.1

(For your reference)

Additional Brief explanation of the drawings

(have been described in the specification and the drawings, but not been shown in the list of the brief explanation of the drawings in JP 09-29032P)

40 substrate

41 pixel electrode

42 opposing electrode

43 polarizing plate

44 polarizing plate

45 polarization axis

46 polarization axis

47 transverse electric field

48 initial orientation direction

List of drawing numerals of between thr e applications for contrasting above numerals

A : Japanese Patent Application No. 08-286642

B : Japanese Patent Application No. 09-029032

C : U.S. Patent Application No. 08/960,224

P. A. : Prior Art

A	C		B	C	
1	11		1	19	
2	12		2	20	
3	13		3	21	
4	14		4	22	
5	15		5	23	
6	16		6	10	P. A.
7	17		7	24	
8	18		8	25	
9	1	P. A.	9	26	
10	2	P. A.	10	27	
11	3	P. A.	11	5	P. A.
12	4	P. A.	12	6	P. A.
			13	7	P. A.
			14	8	P. A.
			15	9	P. A.